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HICAP

HIGH CAPACITY DIGITAL RADIO TRENDS THROUGH THE YEAR 2000

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TRENDS
FREE WORLD/EUROPE

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SINGULAR TREND TOWARD SPECTRAL EFFICIENCY

- MULTI-LEVEL MODULATIONS
- DUAL-POLARIZATION
- HIGHER FREQUENCIES
- FREQUENCY REUSE

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MULTIPATH COUNTERMEASURES AND INTERFERENCE CANCELLERS NEEDED

TECHNOLOGIES IN DEVELOPMENT:

FORWARD ERROR CORRECTION/COMPLEX CODING
ROBUST SPECTRUM SHAPING
PREDISTORTION TECHNIQUES
HIGHLY LINEAR AMPLIFIERS
HIGH PERFORMANCE ANTENNAS
SPACE DIVERSITY
MULTI-CARRIER TRANSMISSION

ROBUST CARRIER RECOVERY AND DECISION CIRCUITRY
TRANSVERSAL EQUALIZERS
MATCHED FILTERS

RAIN ATTENUATION COUNTERMEASURES

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RF FREQUENCY TRENDS

❑ CURRENT

2-40 GHZ CHANNEL PLANS

LONG-HAUL PRIMARILY ON RF'S UNDER 12 GHZ (4 AND 6 GHZ)

SHORT-HAUL PRIMARILY ON RF'S OVER 12 GHZ
(13, 15, 18, 20, 23, 28, 28)

❑ FUTURE

LITTLE CHANGE -- DOWNWARD COMPATIBILITY REQUIRED

NEW CAPACITY POSSIBLY AT 8 AND 11 GHZ

MAJORITY OF LONG HAUL DIGITAL IN 4 AND 6 GHZ (4 AND 5 GHZ I

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CHANNEL BANDWIDTH TRENDS

- **CURRENT**

  20, 30, AND 40 MHZ SPEC'D BY CCIR

- **FUTURE**

  LITTLE CHANGE--DOWNWARD COMPATIBILITY REQUIRED

  EXPANDED BANDWIDTHS WILL OCCUR AT HIGHER RF'S

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MODULATION TRENDS

- **CURRENT**
  - QPSK AND 16 QAM USED EXTENSIVELY
  - 64 QAM POPULAR IN NORTH AMERICAN NETWORK ON 6 GHZ
- **FUTURE**
  - MAXIMIZE CAPACITY FIRST WITH DUAL-POLARIZED 16 QAM
  - MORE 64 QAM DEPENDING ON BIT RATE/BW COMBINATION
  - 256 QAM FIELD TRIALS BEGAN IN 1985

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TECHNOLOGY TREND SUMMARY

PROMISING FUTURE TECHNOLOGIES IN DIGITAL RADIO

Technique	Increases In—	Problems	Countermeasures and Key Technologies	Realization Time Frame*
Super Multi-Level Modulation	Radio Channel Capacity	Waveform Distortion Residual Errors Fading	Transversal Equalizers, Matched Filters, Space Diversity, Multi-Carrier, Coded Modulation, Forward Error Correction, Microwave Digital Processing	256QAM: 1980s 256X256QAM: 2020s
Dual-Polarization	Radio Channel Capacity (2 fold)	XPD	High XPD Antennas, Transversal-Type Cancellers	1990s
One-Frequency Repeating	Route Capacity (2 fold)	Transmit/Receive Interference	Transversal-Type Cancellers, Transmitting Power Control, Network Control	1990s
High Density Branching	Nodal Capacity (3-4 fold)	Branch Route Interference	Interference Cancellers, High Directivity Antennas, Network Control	2000s
Higher Frequency Bands	Route & Nodal Capacity (2 fold)	Rain Attenuation RF Circuit	MICs, Monolithic MICs, GaAs Amplifiers, Linearizers, Analog-Digital Hybrid Repeaters	Sub-Millimeter: 1990s Millimeter: 2010s
Route Diversity	Nodal Capacity (2 fold)	Switching Control Fading Rain Attenuation	Hitless Switching, Network Control, Satellites	2000s

* Time frames beyond the year 2000 are estimates or goals.

IEEE Communications Magazine
Oct. 1986

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MODULATION LEVEL BY CHANNEL BW AND BIT RATE

	CHANNEL BW / BIT RATE	20 MHz	30 MHz	40 MHz
USSR EUROPE BLOC	34 Mb/s	4-PSK	4-PSK	4-PSK
	68 Mb/s	16-QAM	8-PSK	4-PSK
	140 Mb/s	256-QAM	64-QAM	16-QAM
	280 Mb/s	------	1024-QAM	256-QAM
NORTH AMERICA	45 Mb/s	••	••	••
	90 Mb/s	64-QAM	16-QAM	8-PSK
	135 Mb/s	256-QAM	64-QAM	16-QAM
	180 Mb/s	1024-QAM	256-QAM	64-QAM
	270 Mb/s	------	1024-QAM	256-QAM

•• FCC REQUIRES A MINIMUM OF 78 Mb/s FOR COMMON CARRIERS

IEEE CCommunication Magazine
Oct 1986

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OTHER FREQUENCY DOMAIN TRENDS

- **DUAL POLARIZATION**
  - WILL HAPPEN BEFORE HIGHER MODULATIONS
  - EUROPEAN PTT'S COMMITTED TO 16 QAM, 140 MBPS IN 40 MHZ CHANNEL
- **HIGHER FREQUENCIES**
  - EVOLUTION TO 34 MBPS AT 15 GHZ AND 140 MBPS AT 13 GHZ FOR EUROPEAN JUNCTION NETWORKS
  - 18, 23, 28, 38 GHZ FOR LOCAL NETWORKS (ISDN, PABX INTERCONNECTS)
- **CO-FREQUENCY OPERATION**
  - NEEDS ROBUST INTERFERENCE CANCELLATION FIRST
  - POTENTIAL TO DOUBLE EXISTING CAPACITY

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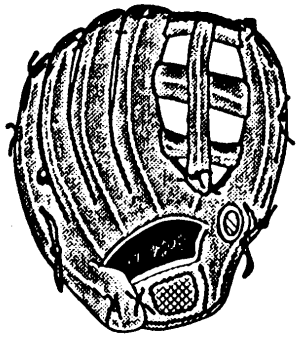
TIME DOMAIN TRENDS

- **CHANNEL ENCODING**
  - ERROR CORRECTION CODES WITH HIGHER MODULATION LEVELS
  - ADDITIVE RESET SCRAMBLERS



- **TDM MULTIPLEX FORMATS**
  - CEPT STANDARD MOST COMMON
  - BELL, JAPANESE, SOVIET WILL BE MAINTAINED
  - NONSTANDARD RADIO LEVEL MULTIPLEXING
  - SOCCER/BASEBALL RULE OF THUMB

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WHY CHOOSE DIGITAL OVER ANALOG?

- TERMINAL EQUIPMENT CHEAPER
- MORE RELIABLE, LESS MAINTAINENCE
- BETTER SIGNAL QUALITY
- TRANSPARENT TO DATA
- SYNERGY WITH DIGITAL SWITCHING
- ADVANCES WITH DEVICE TECHNOLOGY

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FACTORS INFLUENCING RATE OF ANALOG TO DIGITAL TRANSITION

- DEMAND FOR DIRECT DATA SERVICE VS. POTS
- DEMAND FOR QUALITY
- RATE OF TELEPHONE GROWTH
- PRESENT ANALOG INVESTMENT
- DEPRECIATION STRATEGIES
- POLITICAL, ECONOMIC, SOCIAL, DEVELOPMENTS
- GEOGRAPHY

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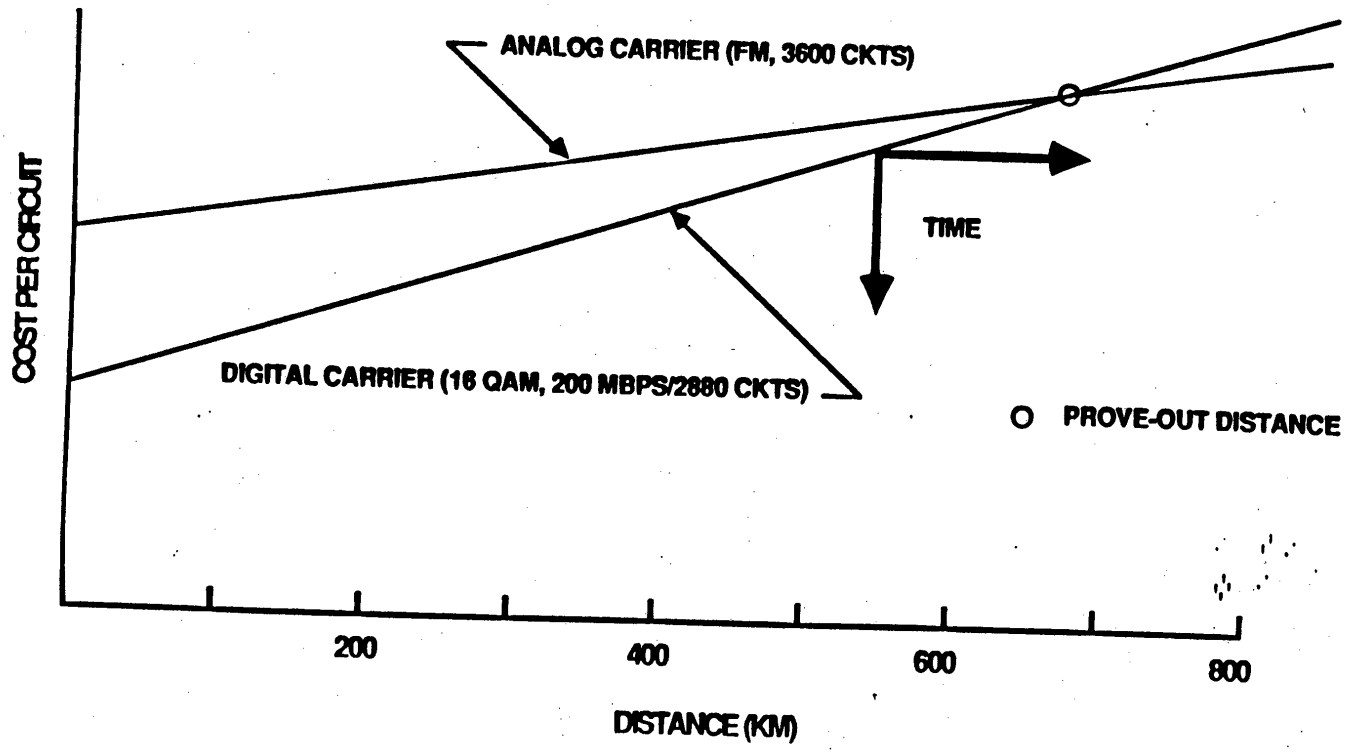
COST PROFILES OF ANALOG AND DIGITAL TRUNK RADIO TRANSMISSION (1981)



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NORTH AMERICAN TRENDS

- **RF COMMON CARRIER ALLOCATIONS:**

  U.S.: 2, 4, 6, 11 GHZ
  CANADA: 2, 4, 6, 8, 11 GHZ

- **STANDARD CARRIER DESIGNS:**

  4 GHZ 2 DS-3 IN 20 MHZ, 16 QAM, 28%
  6 GHZ 3 DS-3 IN 30 MHZ, 64 QAM, 51%
  11 GHZ 3 DS3 IN 40 MHZ, 8-PSK; 21%
  8 GHZ 2 DS-3 IN 40 MHZ

- **CANADA HAS 8 GHZ CROSS-COUNTRY SYSTEM**

- **AT&T COMPLETING 4 GHZ CROSS-COUNTRY SYSTEM**
  MCI OPERATES LONG-HAUL DIGITAL MICROWAVE SYSTEM

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EUROPEAN TRENDS

- RF COMMON CARRIER ALLOCATIONS:

  4, 6 GHZ
  SOME PLANNING AND DEPLOYMENT AT 11 AND 18 GHZ

- STANDARD CARRIER DESIGNS:

  SQUEEZE MULTIPLES OF 140 MBPS INTO
  30 AND 40 MHZ CHANNELS AT 4 AND 6 GHZ

  30 MHZ, 64 QAM DEPLOYMENTS COMPATIBLE WITH ANALOG
  IN LOWER 6 GHZ BAND

- 20-50% TRAFFIC BY RADIO RELAY
  20% OF THIS TRAFFIC BY DIGITAL RADIO RELAY

- FRANCE: MOST DIGITAL COUNTRY AT 56% TRUNK TRANSMISSION

- SWITZERLAND: BEGAN CONVERSION IN '85; COMPLETE IN 40 YRS.

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THIRD WORLD TRENDS

- GREATEST RATE OF GROWTH IN DIGITAL TRANSMISSION

  BOTSWANA: FIRST 100% DIGITAL COUNTRY

- DEPLOYMENTS OF DIGITAL CARRIER BY NEC ALONE (AS OF SEPT. 86)

LATIN AMERICA

ST. VINCENT	13 GHZ 34 MB
VENEZUELA	2, 8, 11 GHZ 13-140 MB
MEXICO	6, 11, 15 GHZ 17-140 MB
EL SALVADOR	7, 8 GHZ 17-34 MB
HONDURAS	2, 8, 11 GHZ 4-90 MB
JAMAICA	2, 11 GHZ 14-78 MB
ARGENTINA	8, 11 GHZ 140 MB
CHILE	2, 13 GHZ 34 MB
BRAZIL	2, 5, 8 GHZ 4-140 MB
PERU	7, 13 GHZ 17-34MB

AFRICA

EGYPT	2 GHZ 4-17 MB
LIBYA	2, 11 GHZ 17-140 MB
TUNISIA	2, 8 GHZ 17-68 MB
ALGERIA	2, 15 GHZ 34-140 MB
ETHIOPIA	11 GHZ 140 MB
SUDAN	2 GHZ 17 MB

ASIA

AUSTRALIA	2, 4, 6, 8, 11, 18, 40, 50 GHZ 2-140 MB
PAPUA NEW GUINEA	2 GHZ 4 MB
INDIA	7 GHZ 34 MB
SRI LANKA	2, 4, 8 GHZ 4-68 MB
PAKISTAN	7 GHZ 34 MB
THAILAND	2, 5, 6, 7, 11 GHZ 17-140 MB
PHILIPPINES	6, 8 GHZ 17-68 MB
SINGAPORE	2, 8, 11 GHZ 13-68 MB
INDONESIA	2 GHZ 17-34 MB
TAIWAN	6, 11 GHZ 90 MB
HONG KONG	2, 7, 11 GHZ 3-45 MB
CHINA	2, 4, 5, 7, 8 GHZ 17-140 MB

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Fujitsu Microwave Radio Equipment

Overseas Supply Record

1986

FUJITSU

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NORTH AMERICA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1985	U.S.A.	MCI Telecommunications Corporation	DM4G-100H (4 GHz Band, 64 QAM)	85
1986	U.S.A.	MCI Telecommunications Corporation	DM4G-100H (4 GHz Band, 64 QAM)	144
		QWEST Microwave Inc.	DM6G-100H (6 GHz Band, 64 QAM)	110
			DM6G-100L (6 GHz Band, 64 QAM)	9
			DM11G-100H (11 GHz Band, 64 QAM)	6
North America Total				354

LATIN AMERICA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1985	Colombia	Empresas Públicas de Medellín (EPM)	DM800-100H (800 MHz Band, 4 PSK)	24
			DM6G-100H (6 GHz Band, 4 PSK)	22
Latin America Total				46

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ASIA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1983	People's Republic of China	Amoi Post and Telecommunications Bureau	DM2G-100H (2GHz Band, 4 PSK)	2
1985	Malaysia	Telecommunications Department (JTM)	DM8G-100H (8GHz Band, 16 QAM)	56
	Thailand	Communication Authority of Thailand (CAT)/ Telephone Organization of Thailand (TOT)	DM8G-100H (8GHz Band, 4 PSK)	4
Asia Total				62

OCEANIA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1982	New Zealand	New Zealand Post Office (NZPO)	DM6G-100H (6GHz Band, 16 QAM)	2
1983	New Zealand	New Zealand Post Office (NZPO)	DM6G-100H (6GHz Band, 16 QAM)	44
			DM4G-100H (4GHz Band, 16 QAM)	16
			DM6G-100H (6GHz Band, 4 PSK)	4
			DM7G-100H (7GHz Band, 4 PSK)	28
			DM11G-100H (11GHz Band, 16 QAM)	14

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OCEANIA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1984	New Zealand	New Zealand Post Office (NZPO)	DM6G-100H (6GHz Band, 16 QAM)	36
			DM7G-100H (7GHz Band, 4 PSK)	28
			DM11G-100H (11GHz Band, 16 QAM)	8
1985	New Zealand	New Zealand Post Office (NZPO)	DM4G-100H (4GHz Band, 16 QAM)	2
			DM6G-100H (6GHz Band, 16 QAM)	168
			DM6G-100H (6GHz Band, 4 PSK)	4
			DM7G-100H (7GHz Band, 4 PSK)	48
			DM11G-100H (11GHz Band, 16 QAM)	8
			DM6G-100H (6GHz Band, 64 QAM)	4
1986	New Zealand	New Zealand Post Office (NZPO)	DM6G-100H (6GHz Band, 16 QAM)	94
			DM11G-100H (11GHz Band, 16 QAM)	5
			DM6G-100H (6GHz Band, 4 PSK)	28
Oceania Total				541

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AFRICA

Contract Year	Country	Customer	Equipment	Quantity (TR)
1979	Algeria	Ministère des Postes et Telecommunications (P et T)	PSK2G-10R (2GHz Band)	12
1983	Algeria	Ministère des Postes et Telecommunications (P et T)	DM2G-100H (2GHz Band, 4 PSK)	8
	Kenya	Kenya Posts and Telecommunications Corporation (KPTC)	DM7G-100H (7GHz Band, 4 PSK)	4
Africa Total				24

MIDDLE & NEAR EAST

Contract Year	Country	Customer	Equipment	Quantity (TR)
1985	Jordan	Telecommunications Corporation	DM2G-100H (2GHz Band, 4 PSK)	56
1986	UAE	The Emirates Telecommunications Corporation Limited (ETISALAT)	DM7G-100H (7GHz Band, 4 PSK)	40
Middle & Near East Total				96

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IMPACT OF COMPETING TECHNOLOGIES

- REVITALIZATION OF HIGH SPECTRUM EFFICIENCY DIGITAL MODEMS FOR DIGITAL DATA TRANSMISSION OVER EXISTING ANALOG RADIO

  19.2 KBPS OVER VGC
  216 KBPS OVER BASIC FDM GROUP
  1.544 (DS-1) OVER FDM SUPERGROUP
  2 DS-3'S OVER FDM HYPERMASTER GROUP

- OPTICAL FIBER DEPLOYMENTS

  AT&T'S FIBER CAPACITY TODAY EQUIVALENT TO ENTIRE BELL LONG-HAUL NETWORK OF 1980

  ENORMOUS BANDWIDTH CAPACITY MAY SOFTEN RATE OF DIGITAL RADIO DEPLOYMENTS

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TRENDS
SOVIET AND BLOC

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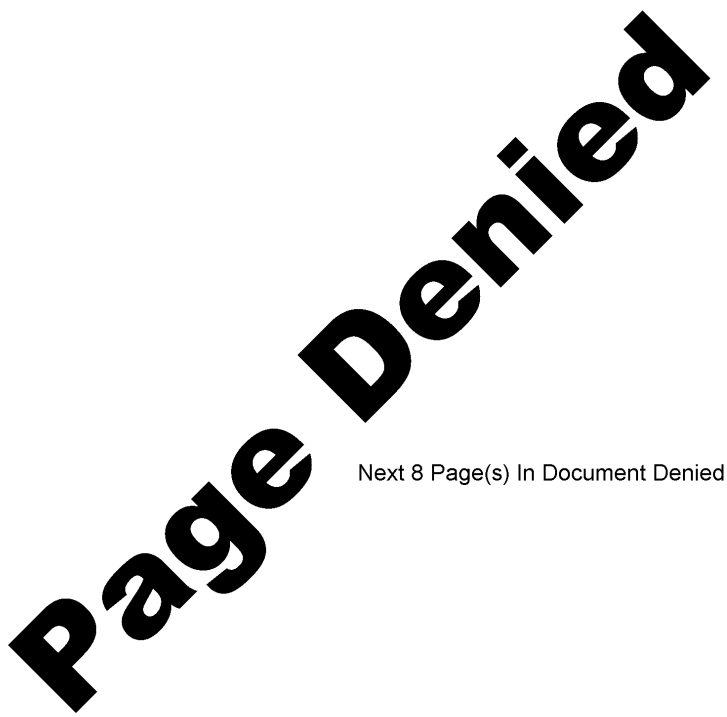

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WILD-CARD SCENARIO

- GLASNOST/GORBACHEV REFORMS COULD QUICKEN PACE OF TELECOM DEVELOPMENT
- DOMESTIC INDUSTRY UNABLE TO MEET DEMAND
- WESTERN EQUIPMENT FLOWS WITH RELAXED RESTRICTIONS ON EASTERN BLOC SALES

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CONCLUSIONS

- STRONG TREND IN WEST, THIRD WORLD, AND CHINA TOWARDS DIGITAL RADIO RELAY
- SOVIETS PROGRESSING VERY SLOWLY; HIGH CAPACITY DIGITAL RADIO YEARS AWAY
- ANALOG NOT DEAD YET

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